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Report 1986

EFFECTS OF CORROSION INHIBITORS ON THE WATER COALESCING CHARACTERISTICS OF MILITARY STANDARD FILTER/COALESCER ELEMENTS (INTERIM REPORT)

by

Shirley B. Boulware

September 1970

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

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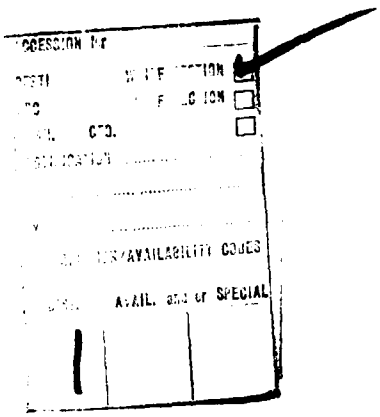

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Report 1986

EFFECTS OF CORROSION INHIBITORS ON THE WATER COALESCING CHARACTERISTICS OF MILITARY STANDARD FILTER/COALESCER ELEMENTS (INTERIM REPORT)

Task 1J662708D50602

September 1970

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Prepared by

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Fuels Handling Equipment Division
Mechanical Technology Laboratory

SUMMARY

This interim report covers a study of the effects of seven corrosion inhibitors on the coalescing characteristics of the DOD-type filter/coalescer elements used to decontaminate liquid hydrocarbon fuels. These corrosion inhibitors are specified for use in military jet fuels (Specification MIL-I-25017, "Inhibitors, Corrosion, Fuel Soluble"). They are identified by their trade names and manufacturers as Santolene-C, Monsanto Chemical Co.; RP-2 and AFA-1, E. I. DuPont de Nemours & Co.; Lubrizol, Lubrizol Corp.; Tolad 244, Petrolite Corp.; TRI-182, Texaco, Inc.; and Unicor M, Universal Oil Products Co. One-percent, water-removal tests and Water Separometer Index (Modified) (WSIM) investigations and analyses were conducted.

This research was carried out by the Fuels Surveillance and Technology Branch, Fuels Handling Equipment Division, USAMERDC.

The report concludes that:

a. The corrosion inhibitors did not produce any adverse effects on the ability of military standard filter/coalescer elements to remove 1-percent water from JP-5 fuel that had been treated with fuller's earth.

b. The free-water content of the fuel passed through the filter/coalescer elements during the 1-percent water injection tests ranged from 0 to 2.0 parts per million (ppm) which is within specification limits.

c. The WSIM's of the inhibited JP-5 fuel during the tests were between 16 and 70.

d. The low, free-water content did not correlate directly with the relatively low WSIM's.

e. The WSIM cannot be used solely to determine the ability of a military standard filter/coalescer element to decontaminate inhibited JP-5 after it has been treated with fuller's earth. However, the WSIM does give an indication of the ability of a filter/coalescer element to decontaminate uninhibited JP-5.

FOREWORD

Authority for the evaluations described in this report is contained in CDOG paragraph 1610(e) which states, "Every means of . . . improving the handling of POL must be exploited."

The work was conducted under Task 1J662708D50602, "Fuels Decontamination Research," under the general supervision of T. H. Jefferson, Chief, Fuels Surveillance and Technology Branch, Fuels Handling Equipment Division.

Other personnel participating in the program were Shirley B. Boulware, Project Chemist, and L. T. Mitchell, Test Mechanic.

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[illegible] ON THE [illegible] CHARACTERISTICS OF MILITARY STANDARD FILTER/COALESCER ELEMENTS

INTERIM REPORT

[illegible]

1. Summary. [illegible] MIL-I-25017 [illegible]

2. Purpose of Tests. Corrosion additives are incorporated in fuels to [illegible] and improve their performance. [illegible] in field service, these additives have been found to adversely affect the ability of military standard-dimension filter/coalescer elements to remove contaminants to the extent required by Specification [illegible], "Filter Separators, Aviation and Motor Fuel, Ground and Shipboard Use, Performance Requirements and Test Procedures For." The purpose of the tests conducted in this study was to determine the magnitude of the adverse effects of the additives. JP-5 fuel was used as a test fuel, and the effects of seven different corrosion inhibitors specified for use in military jet fuels were studied. The concentrations of inhibitors were prescribed by the Qualified Products List (QPL) of inhibitors qualified under Specification MIL-I-25017.

The corrosion inhibitors utilized were Santolene C, Monsanto Chemical Co.; [illegible] Corp.; Tolad 244, Petrolite Corp.; TRI-182, Texaco Inc.; Unicor M, [illegible] Oil Products Co.; and RP-2 and AFA-1, E. I. DuPont de Nemours & Co.

3. **Background.** Specification MIL-I-25017 contains a list of seven corrosion inhibitors which are approved for use in fuels conforming to Specifications VV-G-76, "Automotive Gasoline"; MIL-G-3056, "Automotive Combat Gasoline"; MIL-G-5572, "Aviation Gasoline"; and MIL-J-5624, "JP-4 and JP-5 Turbine Fuels." Each corrosion inhibitor/JP-5 fuel combination was utilized in the tests. Specification MIL-F-8901 states that the only corrosion inhibitor to be used in combination with JP-5 fuel is Santolene C. The additional six corrosion inhibitors in combination with JP-5 fuel have never been used to evaluate the performance of the military standard filter/coalescer elements by this installation.

II. INVESTIGATION

4. **Description of Test Facility.** The test facility consisted primarily of a closed test loop, portions of which were glass, a 100-gallon storage tank, a 20-gpm centrifugal pump, water injection equipment, sample withdrawal apparatus, a clean-up filter/separator, and suitable instrumentation. (See figure for schematic drawing.)

5. **Test Filter/Coalescer Elements.** The military, standard-dimension filter/coalescer elements utilized in the test series were Filters, Inc. Model I-4208, fabricated to conform to the requirements of Specification MIL-F-52308, "Filter Element, Fluid Pressure."

6. **Performance Requirements.** The water-removal performance requirement of Specification MIL-F-8901 states that the filter/coalescer element shall decontaminate inhibited fuel into which 1 percent water is being injected at rated fuel flow. When analyzed with in-line instrumentation, the effluent fuel shall contain not more than 5 parts per million (ppm) by volume of undissolved water. The differential pressure across the filter/separator test vessel with a new element installed and clean fuel (containing no undissolved water and not more than 0.5 mg per liter of solids contamination) shall not exceed 10 pounds per square inch (psi) at any flow rate up to 115 percent of rated flow when measured across the inlet and outlet connections.

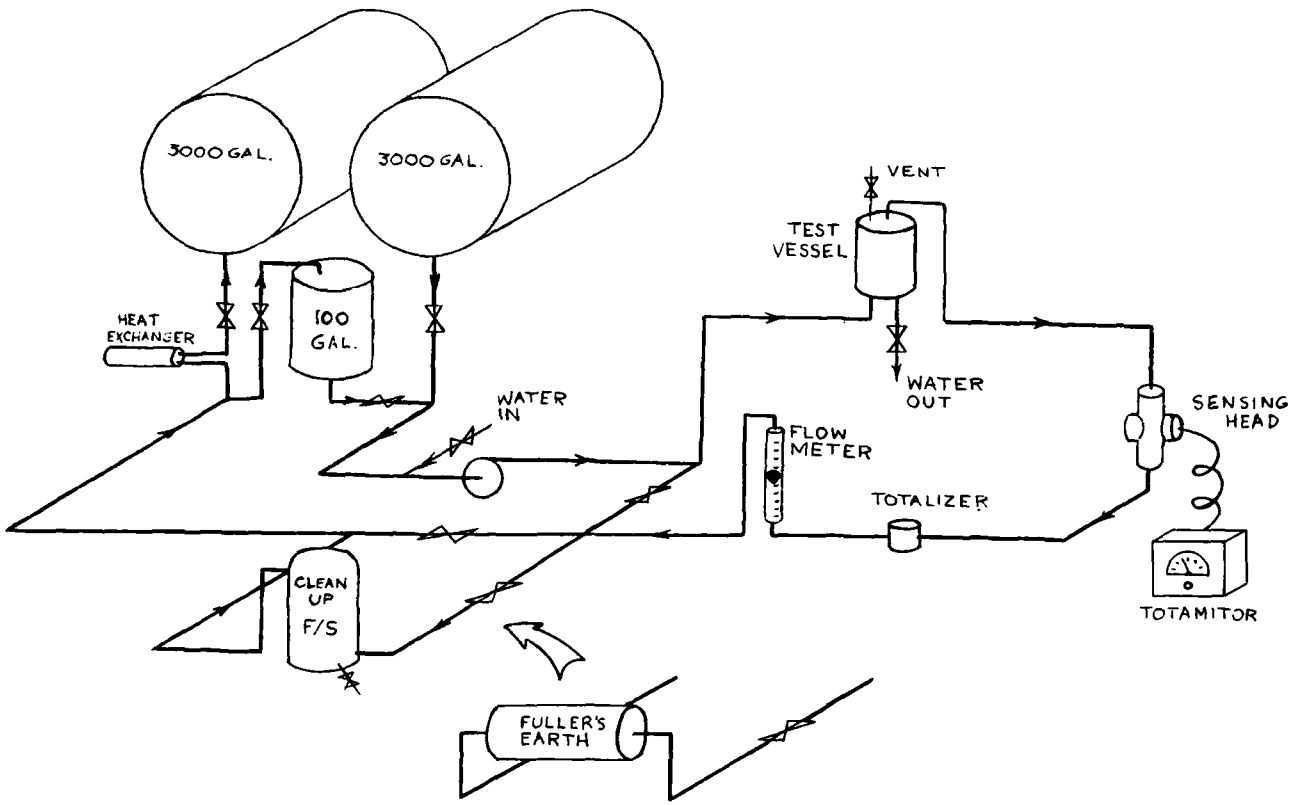
7. **Test Fuel and Contaminant.** JP-5 fuel conforming to Specification MIL-T-5624 was used as the test fuel. The fuel was treated with fuller's earth, and the WSIM prior to the addition of inhibitors was 96. Data are recorded stating WSIM's after the addition of specific inhibitor concentrations.

The water injected into the test fuel during tests was supplied by the Fort Belvoir water utility system. Prior to use in the test as an injected contaminant, water was filtered to a residual solids level of less than 1.0 mg per liter. The pH factor varied from 6.5 to 7.0.

8. **Sample Analysis Procedure.** Samples were analyzed for water-separation properties and free-water content. The following methods were employed:

a. Water-separation properties of the fuel were determined with a Water Separometer. This instrument measures the WSIM which is an indication of the ability of a fuel or a fuel/additive combination to release entrained or emulsified water when passed through a coalescer-type water separator.

b. Free-water content of the filter/separator effluent during the test was monitored by a Bowser Totamitor Model 871 installed in the effluent portion of the



Schematic Drawing of Single-Elem[illegible], Glass-Pipe Test Loop.

system. This instrument operates on a light-scattering principle; a beam of light is diffused or reflected by minute water droplets suspended in the fuel. The magnitude of light scattering is indicated on a dial (galvanometer) scaled to read in ppm of free water.

9. **Test Procedures and Results.** Prior to the initiation of tests, 2400 gallons of JP-5 fuel was treated by passing the fuel through fuller's earth filters to obtain a minimum WSIM number not less than 85. At the start of each test, 90 gallons of this treated fuel was pumped into the 100-gallon storage tank, which was part of the closed test loop, and the appropriate quantity of corrosion inhibitor was blended for 20 minutes by circulation while by-passing the test vessel and clean-up filter/separator.

Upon completion of blending, three 1-gallon samples were taken for WSIM analyses. The fuel was then pumped through the test system, including the clean-up filter/separator, at 20-gpm flow rate to obtain the blank totamitor and pressure readings. One-percent water was then injected for 15 minutes at the pump inlet. Totamitor and pressure readings were taken every 5 minutes for the duration of the 15-minute, water-injection period.

A new filter/coalescer element was used with the test run for each corrosion inhibitor. It was first exposed to the 1-percent, water-removal test using test fuel containing the minimum concentration of corrosion inhibitor as prescribed in Specification MIL-I-25017. If the filter/coalescer element demonstrated the ability to reduce the effluent fuel to 5 ppm or less free water, the same element was exposed to a second 1-percent, water-removal test with fuel containing the maximum concentration of corrosion inhibitor. At the completion of each corrosion-inhibitor test, the entire test system (loop) was thoroughly cleaned and flushed with water to remove any residual quantity of corrosion inhibitor prior to conducting the next test.

Results of the tests are recorded in Tables I through VIII.

III. DISCUSSION

10. **Free-Water Content and WSIM Data.** Theoretically, free water is undissolved water in excess of the water in solution of a fuel. The free-water content as measured by the Totamitor equals the total-water content minus the quantity of water in solution. The adjusted free-water content (total free-water content less the blank) of the test fuel in this study ranged from 0 to 2 ppm. Although the Water Separometer can be modified to semi-quantitatively measure free-water content, its main purpose was to measure the ease with which a fuel will release free water.

Table I. Santolene-C Data

Inhibitor Concentration (lb/1000 bbl)	Time (min)	Fuel Flow (gpm)	*Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	20	92	2.0	0.80	61
4	5	20	92	2.5	0.90	–
4	10	20	92	2.5	0.90	–
4	15	20	92	2.5	0.90	–
16	0	20	85	2.0	0.90	34
16	5	20	85	3.0	0.95	–
16	10	20	85	3.0	0.95	–
16	15	20	85	3.0	0.95	–

* In several instances throughout this series of tests, the fuel temperature exceeded the 70 to 90° F range specified in Specification MIL-F-8901 because the test loop was not equipped with any type of heat exchanger.

Table II. AFA 1 Data

Inhibitor Concentration (lb/1000 bbl)	Time (min)	Fuel Flow (gpm)	*Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
4	0	20	92	2.0	0.9	37
4	5	20	92	2.0	0.9	–
4	10	20	93	2.0	0.9	–
4	15	20	93	2.0	0.9	–
16	0	20	84	2.0	0.7	43
16	5	20	84	2.5	1.1	–
16	10	20	84	2.5	1.2	–
16	15	20	84	2.5	1.3	–

* In several instances throughout this series of tests, the fuel temperature exceeded the 70 to 90° F range specified in Specification MIL-F-8901 because the test loop was not equipped with any type of heat exchanger.

Table III. Lubrizol Data

Inhibitor Concentration (lb/1000 bbl)	Time (min)	Fuel Flow (gpm)	*Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	20	91	1.5	1.0	67
5	5	20	90	2.0	0.9	–
5	10	20	90	2.5	0.9	–
5	15	20	90	2.5	0.9	–
20	0	20	80	2.5	1.0	45
20	5	20	80	3.5	2.5	–
20	10	20	80	3.5	2.7	–
20	15	20	80	3.5	2.8	–

* In several instances throughout this series of tests, the fuel temperature exceeded the 70 to 90° F range specified in Specification MIL-F-8901 because the test loop was not equipped with any type of heat exchanger.

Table IV. TR1-182 Data

Inhibitor Concentration (lb/1000 bbl)	Time (min)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
17.5	0	20	78	2.0	0.80	70
17.5	5	20	79	2.5	0.85	
17.5	10	20	79	2.5	0.90	
17.5	15	20	79	3.0	1.00	
20	0	20	80	2.0	0.75	68
20	5	20	81	2.5	2.10	
20	10	20	81	2.5	2.60	
20	15	20	81	2.5	2.50	

Table V. Tolad 244 Data

Inhibitor Concentration (lb/1000 bbl)	Time (min)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
5	0	20	76	2.0	0.90	62
5	5	20	76	2.5	0.95	–
5	10	20	77	3.0	0.90	–
5	15	20	77	3.0	0.95	–
20	0	20	81	2.5	1.30	56
20	5	20	82	3.5	3.50	–
20	10	20	82	3.5	3.40	–
20	15	20	82	3.5	3.30	–

Table VI. Unicor-M Data

Inhibitor Concentration (lb/1000 bbl)	Time (min)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
9	0	20	76	2.0	0.85	16
9	5	20	77	2.5	0.90	–
9	10	20	77	2.5	0.90	–
9	15	20	78	2.5	0.90	–
20	0	20	80	2.0	0.75	23
20	5	20	81	3.0	1.00	–
20	10	20	81	3.0	1.00	–
20	15	20	81	3.0	1.10	–

Table VII. RP-2 Data

Inhibitor Concentration (lb/1000 bbl)	Time (min)	Fuel Flow (gpm)	Fuel Temp (°F)	Diff. Pressure (psi)	Totamitor (ppm)	WSIM
7	0	20	79	3.0	0.80	57
7	5	20	79	4.0	0.85	–
7	10	20	79	4.0	0.80	–
7	15	20	79	4.3	0.80	–
20	0	20	86	4.5	0.85	49
20	5	20	86	5.0	1.00	–
20	10	20	86	5.0	0.90	–
20	15	20	86	5.0	0.90	–

Table VIII. General Summary of Corrosion Inhibitor Data

Corrosion Inhibitor	Concentration (lb/1000 bbl)	Free-Water Content–(ppm) (Total less blank)	WSIM	Diff. Pressure (psi)
San-C	4	0.10	61	2.5
San-C	16	0.05	34	3.0
AFA-1	4	0.00	37	2.0
AFA-1	16	0.60	43	2.5
Lubrizol	5	0.00	67	2.5
Lubrizol	20	1.80	45	3.5
TR1-182	17.5	0.20	70	3.0
TR1-182	20	1.80	68	2.5
Tolad 244	5	0.05	62	3.0
Tolad 244	20	2.00	56	3.5
Unicor M	9	0.05	16	2.5
Unicor M	20	0.40	23	3.0
RP-2	7	0.00	57	4.3
RP-2	20	0.05	49	5.0

Uninhibited JP-5 fuel received directly from the refinery without a fuller's earth treatment generally has a WSIM between 85 and 100 and is thought to be relatively surfactant-free—that is, free of surface-active agents. It is acceptable in that it can usually be decontaminated without difficulty by a filter/separator using military standard filter/coalescer elements. JP-5 fuel not previously treated with fuller's earth and with a WSIM between 70 and 84 is unpredictable in that passing and failing performances have both been experienced in filter/separator operation. The JP-5 fuel specification requirement for WSIM is a minimum of 85. In general, untreated JP-5 fuel would be difficult to decontaminate if the WSIM was between 0 and 69. However, this is not true in reference to treated JP-5 fuel/additive combinations as is shown by the results obtained in this study. Tests using JP-5 fuel inhibited with corrosion inhibitors and having WSIM's ranging from 16 to 70 passed 1-percent water-removal requirements. These results contradict statements on untreated JP-5 fuel given earlier in this paragraph. The author theorizes that the successful water-removal tests were due mainly to the fact that the JP-5 test fuel had been previously treated with fuller's earth. The fuller's earth removed all objectionable surfactants which most likely would have plated out and/or adversely affected filter/coalescer element performance. Examples of these types of objectionable surfactants are sodium sulfonates which are refinery residuals.

It can be seen that it cannot be determined from the WSIM data alone if a corrosion inhibitor will adversely affect JP-5 fuel to the extent that it cannot be decontaminated by a filter/coalescer element.

IV. CONCLUSIONS

11. **Conclusions.** It is concluded that:

a. The corrosion inhibitors did not produce any adverse effects on the ability of military standard filter/coalescer elements to remove 1 percent water from JP-5 fuel that had been treated with fuller's earth.

b. The free-water content of the fuel passed through the filter/coalescer elements during the 1 percent water injection tests ranged from 0 to 2.0 ppm which is within specification limits.

c. The WSIM's of the inhibited JP-5 fuel during the tests were between 16 and 70.

d. The low, free-water content did not correlate directly with the relatively low WSIM's.

e. The WSIM cannot be used solely to determine the ability of a military standard filter/coalescer element to decontaminate inhibited JP-5 after it has been treated with fuller's earth. However, the WSIM does give an indication of the ability of a filter/coalescer element to decontaminate uninhibited JP-5.

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13. ABSTRACT

This interim report covers a study of the effects of seven corrosion inhibitors on the coalescing characteristics of the DOD-type filter/coalescer elements used to decontaminate liquid hydrocarbon fuels. These corrosion inhibitors are specified for use in military jet fuels, Specification MIL-I-25017, "Inhibitors, Corrosion, Fuel Soluble."

The report concludes that:

a. The corrosion inhibitors did not produce any adverse effects on the ability of military standard filter/coalescer elements to remove 1-percent water from JP-5 fuel that had been treated with fuller's earth.

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